REMARKS

Claims 6, 19, 20 and 25-32 are pending. By this Amendment claims 1-3, 7-18 and 21-24 are canceled without prejudice or disclaimer; claims 6, 19, 20, 25 and 26 are amended; and claims 29-32 are added. Reconsideration in view of the above amendments and following remarks is respectfully requested.

Claims 1-3 and 6-28 were rejected under 35 U.S.C. §103(a) over Falster (U.S. Patent No. 6,849,901). The rejection is respectfully traversed.

Claims 6 recites, *inter alia*, (1) removing an oxide film on a surface of a silicon wafer; (2) after removing, vacancy heat treating for forming new vacancies in an interior of the silicon wafer by means of a heat treatment of said silicon wafer, (2-a) at a temperature of 1135 to 1170°C; (2-b) in an atmosphere containing NH_3; (2-c) for a period of between one second and 60 seconds (2-d) so as to nitride the surface of the silicon wafer, wherein (2-e) during the vacancy heat treating, purging is conducted to remove oxygen from the atmosphere surrounding said silicon wafer; (3) quenching the silicon wafer after the vacancy heat treating; (4) SF nuclei heat treating for agglomerating interstitial silicon released during precipitation of oxygen from vacancies injected by the vacancy heat treating, to form stacking fault nuclei, thereby forming SF nuclei layer of high stacking fault nuclei density in the interior near the surface, and (4-a) in the SF nuclei heat treating, a rate of temperature increase is set to 10 °C/minute or less (4-b) a heat treatment temperature is set to 1100 °C or higher and (4-c) the heat treatment temperature is maintained for one hour or more.

In accordance with feature (2), the surface of the wafer is nitrided, and thereby, new vacancies are injected. See, for example, page 13, line 2. A high concentration of vacancies are formed in the interior near the surface by the surface nitriding. See, for example, FIG. 3A. See also the Declaration under 37 C.F.R. § 1.132 of Takaaki Shiota, a co-inventor of the instant application. Therefore, an SF nuclei layer S of high SF nuclei density can be formed in the interior near the surface by the subsequent SF nuclei heat treatment. See, for example, page 14, lines 8-9.

Furthermore, in the vacancy concentration profile, the vacancy concentration decreases as the depth from the surface increases. In other words, vacancy concentration in the interior near the surface is higher than that in the mid-section. See, for example, FIG. 3A and the Declaration. Accordingly, a high strength can be obtained in the mid-section of the silicon wafer. See, for example, page 14, lines 21-22.

In particular, an oxide film is removed in accordance with feature (1), and oxygen is removed in accordance with feature (2-e). Therefore, in the vacancy heat treatment, the silicon wafer, in which the oxide film is removed, is heated in an atmosphere containing NH_3 from which oxygen is removed. Thereby, a sufficient amount of vacancies are injected even at a low temperature of feature (2-a). See, for example, page 13, lines 5-6. The heating temperature of the invention of claim 6 is about 100°C lower than that in the case in which an atmosphere of N_2 is used. See the Declaration.

In comparison with the case in which the silicon wafer is heated at high temperature in the atmosphere of N_2, in the vacancy concentration profile, vacancy concentration decreases more rapidly as the depth from the surface increases in the case in which the silicon wafer is heated at low temperature in the atmosphere of NH_3. See the Declaration. Therefore, a high concentration of vacancies can be formed in the interior near the surface. Moreover, the total amount of vacancies in the whole silicon wafer can be reduced, and especially vacancy concentration can be reduced in the mid-section of the wafer.

Consequently, due to the subsequent SF nuclei heat treating, SF nuclei can be formed at high density in the interior near the surface, where more gettering effect is required. Also, since vacancy concentration in the mid-section of the wafer can be reduced, high strength can be obtained in the mid-section, and thereby, sufficient strength as required for the entire silicon wafer can be obtained. See, for example, page 14, lines 21-22.

Furthermore, since the vacancy heat treatment can be conducted at low temperature, the occurrence of slip dislocations can be prevented. See the Declaration. Therefore, deterioration of strength due to slip dislocation can be prevented, and thereby, sufficient strength as required for the entire silicon wafer can be obtained. See, for example, page 14, lines 21-22.

In contrast, in Falster, as shown in FIG. 5 thereof, a silicon wafer is formed in which vacancy concentration in the interior near the surface is lower than that in the mid-section (center portion). This is a clear difference between the invention of claim 6 and Falster.

In order to realize the vacancy concentration profile having the above feature, the following methods are described in Falster.

(I) <u>The silicon wafer is subjected to a thermal oxidation step S1 so as to form a superficial oxide layer in the surface, and then</u> is subjected to a rapid thermal annealing step S2 in an atmosphere of gas containing nitrogen (first embodiment of Falster).

(II) The silicon wafer is subjected to the rapid thermal annealing step S2 in an atmosphere containing 0.0001 atm or more of O_2 without being subjected to the thermal oxidation step S1 prior thereto (third embodiment of Falster).

(III) The silicon wafer is subjected to a rapid thermal annealing step S2 in an atmosphere of gas containing nitrogen without being subjected to the thermal oxidation step S1 prior thereto, and then is subjected to thermal annealing in an oxygen atmosphere (oxygen annealing) (third embodiment and Example 5 of Falster).

In Falster, vacancies are formed in such a way that the vacancy concentration in a bulk portion is higher than that in the interior near the surface. Thereby, oxygen clusters in the high vacancy region, and oxygen does not cluster in the low vacancy region. See column 10, lines 14-22. As a result, a wafer can be obtained which has substantially uniform interstitial oxygen concentration as a function of distance from the surface. See column 10, lines 63-65. Also, the concentration of interstitial oxygen in the denuded zone will not significantly change as a consequence of the precipitation heat-treatment. See column 11, lines 16-20.

The above method (I) does not correspond to feature (1) of the claim 6, and the above method (II) does not correspond to feature (2-e) of the claim 6. Also, in accordance with methods (I) and (II), prior to or during the rapid thermal annealing S2, a superficial oxide layer is formed in the surface. This superficial oxide layer serves as a shield which inhibits nitridization of the surface. See column 12, lines 14-17. Therefore, neither of methods (I) and (II) correspond to feature (2-d) of the claim 6.

Furthermore, in Falster, since nitridization of the surface is inhibited by the superficial oxide layer, vacancies are formed only by creation of Frenkel pairs. See the Declaration. As expressed by the following equation (A), the vacancy concentration resulting from the creation of Frenkel pairs is dependent only on the annealing temperature, and increases with changes of the annealing temperature at an exponential rate.

$$ns = \exp(S/k)\exp(-Es/kT) \cdots\cdots (A)$$

ns: equibrium concentration of point defects (vacancy concentration), S/k: entropy for forming atomic vacancy and Es: energy for forming atomic vacancy. Since interstitial silicon diffuses quickly, the concentration of interstitial silicon can be expressed as the concentration of vacancies.

Considering equation (A), in the case of forming vacancies by creation of Frenkel pairs, it is necessary to set the annealing temperature to as high as possible so as to form a

sufficient amount of vacancies. Falster discloses that the annealing temperature of the rapid thermal annealing S2 is generally more than 1150°C. However, the annealing temperature is most preferably 1200 to 1275°C. See column 8, lines 22-25. 1200°C and 1250°C are employed in the examples of Falster. In the case in which the annealing temperature is low, the annealing time must be long. Therefore, it is not possible for methods (I) and (II) of Falster to correspond to both features (2-a) and (2-c) of claim 6.

In the case in which vacancies are formed only by creation of Frenkel pairs, as shown in FIG. 5 of Falster and the Declaration, vacancies are formed in such a way that vacancy concentration near the surface is lower than that in the mid-section, and a high concentration of vacancies cannot not be formed near the surface at low temperature as with the present invention.

Furthermore, in Falster, there is no description or suggestion of formation of SF nuclei. Even in the case in which the SF nuclei heat treating of the present invention is applied to Falster, since a high concentration of vacancies are not formed near the surface, the feature of forming an SF nuclei layer of high stacking fault nuclei density in the interior near the surface, which is feature (4) of claim 6, cannot be satisfied.

In the above described method (III) of Falster, vacancies are injected by surface nitriding as in claim 6. In Example 5 of Falster, as the rapid thermal annealing S2, a silicon wafer in which only a native oxide layer is present in the surface, is heat treated in an atmosphere of NH_3 at 1180°C for about 3 minutes. The annealing conditions are similar to those of claim 6. However, in Falster, since it is necessary to inject a sufficient amount of vacancies into the mid-section of the wafer, neither of features (2-a) and (2-c) is met by Falster.

In the case of annealing in an atmosphere of NH_3 at 1180°C, a portion appears in which a large amount of slip dislocations are created, and thereby, reduction (deterioration) of strength due to slip dislocation cannot be inhibited sufficiently. See the Declaration.

Furthermore, in the case in which vacancies are injected by surface nitriding (method (III)), subsequent oxygen annealing is essential for Falster. In Example 5 of Falster, as the oxygen annealing, the silicon wafer is subjected to annealing (rapid thermal annealing) in an atmosphere containing about 100% oxygen at about 1180°C for about 3 minutes. Thereby, an inward flux of silicon self-interstitials is created, which has an effect of gradually altering the vacancy density profile by causing recombinations to occur, beginning at the surface and then moving inward. See column 12, lines 45-55.

Therefore, even in the case in which the SF nuclei heat treating of the present invention is applied to Falster, since a high concentration of vacancies are not formed near the surface, the feature of forming an SF nuclei layer of high stacking fault nuclei density in the interior near the surface, which is feature (4) of claim 6, cannot be satisfied.

As described above, it is essential for Falster to form vacancies in such a way that vacancy concentration near the surface is lower than that in the center portion (mid-section). In contrast, in claim 6, a high concentration of vacancies are formed in the interior near the surface due to surface nitriding as shown in FIG. 3A, and the wafer in which a high concentration of vacancies are present in the interior near the surface, is subjected to SF nuclei heat treating. Consequently, unexpected results can be obtained in which SF nuclei at high density can be formed at a depth required for gettering, and high strength can be obtained in the mid-section of the wafer. This is a difference between claim 6 and Falster. The invention of claim 6 thus has features which are neither disclosed nor suggested by Falster, including unexpected results.

Claims 19, 20 and 25-32 recite additional features of the invention and are allowable for the same reasons discussed above with respect to claim 6 and for the additional features recited therein.

Reconsideration and withdrawal of the rejection of claims 1-24 over Falster are respectfully requested.

In view of the above amendments and remarks, Applicants respectfully submit that all the claims are allowable and that the entire application is in condition for allowance.

Should the Examiner believe that anything further is desirable to place the application in better condition for allowance, the Examiner is invited to contact the undersigned at the telephone number listed below.

Respectfully submitted,

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Attachment:
Rule 132 Declaration